

## REPLY

This timely filed Reply is responsive to the Office Action mailed May 18, 2005. Claims 1-23 were pending at the time of the Office Action. All claims were rejected.

In this Reply, claim 2 and 16 have been amended. No new matter has been added.

Claim 2 was rejected under 35 U.S.C. § 112, second paragraph, based on the assertion that the word "near" lacks a basis for comparison. Claim 2 has been amended to remove the word "near". Accordingly, the rejection under 35 U.S. C. 112, second paragraph is now overcome.

Claims 1-9, 16-23 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Sharma et al. (U.S. Pat. no. 6,730,275; referred to herein as "Sharma '275") in view of a paper by Sharma et al., "A Preliminary Study of Pulsed Streamer Corona Discharge for the Degradation of Phenol in Aqueous Solutions" (Hazardous Waste & Hazardous Materials, vol. 10, no. 2, 1993, pp. 209-219; referred to herein as the "Sharma paper").

Specifically, the Examiner asserts that:

Regarding claim 1, Sharma et al. '275 teach a reactor in Figure 1. Having an electrode 114 in the form of a ground electrode in contact with the aqueous mixture 102. (Column 6 lines 6-8) An electrode 110 is located in a position above a surface 112 of the aqueous mixture 102. (Column 6 lines 5-6) A power supply is provided for applying an electrical potential to the electrodes 110, 114 for creating corona discharge. (Column 6 lines 9-12)

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The differences between Sharma et al. '275 and the present claims is the locating of Sharma et al. '275 ground electrode to the central location and of the chamber and providing an electrode in the aqueous medium for generating discharge is not discussed (Claim 1), the position of the central electrode is not discussed (Claim 2), the reactive liquid phase species are not discussed (Claim 4), the discharge across the liquid is not discussed (Claim 16), the reactive liquid species are not discussed (Claim 18).

Regarding the limitation of claim 1 where the ground electrode is in a central location and an electrode is provided in the aqueous medium, Sharma et al. teach in Fig. 2 locating a ground electrode in a central location of a chamber and locating an electrode below the ground electrode for generating corona discharge in an aqueous

medium. (See Fig. 2; page 212) A power supply is connected between the electrodes for generating the discharge. (See page 212; Fig. 2)

Applicants agree that Sharma '275 discloses a two electrode reactor having a first electrode in the gas phase and a second electrode in the liquid phase. Applicants also agree that Sharma '275 does not disclose Applicants' claimed third electrode, which is a ground electrode disposed between the liquid phase electrode and the gas phase electrode.

Regarding the Sharma paper, Applicants agree that the reactor disclosed in the Sharma paper is a two electrode system, where both electrodes are disposed in the liquid phase.

Based on the reasoning copied below, the Examiner asserts that it is obvious to modify the two electrode reactor disclosed by Sharma '275 to obtain Applicants' claimed three electrode reactor by adding one of the two electrodes from the reactor disclosed in the Sharma paper.

The motivation for locating the ground electrode to the central location of the chamber and providing an electrode in the aqueous medium for generating discharge, by positioning the central electrode, by discharging across the liquid and generating the reactive liquid species because it allows for breakdown of phenols in liquid form.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have modified Sharma et al. '275 by locating the ground electrode to the central location of the chamber and providing an electrode in the aqueous medium for generating discharge, by positioning the central electrode, by discharging across the liquid and generating the reactive liquid species as taught by Sharma et al. because it allows for breakdown of phenols in liquid form.

Applicants respectfully disagree with the above assertion of obviousness based on modifying the two (2) electrode Sharma '275 arrangement to add a third electrode to provide "discharging across the liquid and generating the reactive liquid species" to "allow[s] for breakdown of phenols" for reasons detailed below.

Applicants will now review the cited Sharma references. Sharma '275 is entitled "Corona method and apparatus for altering carbon containing compounds" and discloses a method and apparatus for altering a carbon-containing compound in an aqueous mixture. Sharma has an electrode in the liquid and an electrode in the gas phase. The corona discharge is in the gas phase as well as at the surface of the liquid phase in certain disclosed electrode arrangements.

The Sharma paper discloses pulsed corona discharges to be effective at breaking down phenol in aqueous solutions in an isothermal batch reactor and in a semi-batch reactor with the continuous addition of oxygen. The two electrodes disclosed are both in the liquid phase as is the resulting corona discharge.

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Applicants note the reasons I, II and III that there is no motivation to modify the two (2) electrode Sharma '275 arrangement to add a third electrode to provide "discharging across the liquid and generating the reactive liquid species" to "allow[s] for breakdown of phenols"

I. Sharma '275 already discloses a two (2) electrode arrangement that generates a liquid phase discharge which inherently results in reactive liquid phase species, at least at the surface of the liquid:

As disclosed in col 2, lines 40-61, Sharma '275 teaches that by using an electrode above a liquid surface and an electrode in contact with the liquid, the corona is both in the gas phase and at the liquid surface.

Corona discharges are relatively low-power electrical discharges that can be initiated at or near ambient conditions. *The corona is in the gas phase and, when generated with an electrode above a liquid surface and an electrode in contact with the liquid, the corona is also immediately on the liquid surface.* It should be noted that corona discharge is not merely another configuration of electrolysis where chemical reactions are accomplished by charge transfer oxidation and reduction. Hickling et al. (cited above) proved that charge transfer is only a minor factor in corona discharge and that the chemical effects are fundamentally different. Most noticeably, many equivalents of chemical reaction can be accomplished for each electron of charge transfer. Each electron accelerating through the electric field collides with many gas molecules creating other charged particles and neutral active species (free radicals and atoms). Depending on the conditions of the discharge active species accounting for between 8 and 180 reactions have been measured for each electron of charge transferred. These can bring about ionization, excitation or dissociation of solvent molecules by collision; in addition to charge transfer reactions observed in a typical electrochemical process.

At the time of the invention, the surface of the liquid was thought to be generally more reactive than the bulk of the liquid. Accordingly, since Sharma '275 already generates a corona in the liquid interface, there is little or no motivation to add a central ground electrode because a corona in the liquid and resulting reactive liquid species already exist.

II. The Sharma two (2) electrode arrangement already dissociates solvent molecules in water to form highly reactive free radicals

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Sharma '275 teaches that the corona generated by the two electrode arrangement already dissociates solvent molecules in water to form highly reactive free radicals as noted in col. 3, line 52 to col. 4, line 3 copied below.

It is hypothesized that when corona discharge dissociates solvent molecules in a water system it can form free radicals, .H, and .OH. The .OH, hydroxyl, radical is an extremely aggressive oxidizer (oxidation potential 2.80 Volts) and the primary species considered active in advanced oxidation technologies such as UV/O<sub>3</sub> and UV/peroxide (and Fenton's reagent, Fe/peroxide). The energy requirement for PCP destruction by corona discharge was compared with that of UV/O<sub>3</sub> process (electricity to power the lamps and generate O<sub>3</sub>) and was found to substantially match. Further experiments also investigated the destruction of perchloroethylene and carbon tetrachloride with corona discharge. Each was destroyed in laboratory tests to 99+%. These carbon-containing compounds are not considered oxidizable (Perox-pure, a UV/peroxide process cannot successfully treat these carbon containing compounds). Although, the mechanism has not been elaborated, another reaction pathway, besides oxidation by .OH, is believed to play a critical part.

Accordingly, Sharma '275 teaches that there is no need for liquid phase corona discharge, particularly for reductive processes. Therefore, there is no motivation to add an extra electrode to Sharma '275, such as Applicants' central ground electrode.

### III. Sharma '275 already efficiently breaks down phenols

According to the Examiner the motivation to add Applicants third central electrode to Sharma '275 is to allow "discharging across the liquid and generating the reactive liquid species" to "allow[s] for breakdown of phenols". However, Sharma '275 teaches efficient breakdown of phenols (e.g. PCP) in liquid form using his two (2) electrode arrangement. Examples 6-10 also provide data showing efficient breakdown of phenols (PCP) in liquid form. Col. 5, lines 14-38, disclose the following:

Carbon containing compounds that may be present in the aqueous mixture which are the target of the present invention are those compounds that are considered "unoxidizable" or difficult to oxidize. Non-oxidizable or difficult to oxidize compounds may be defined functionally as those compounds having a substantial portion pass through an oxidative process without modification. Oxidative processes include but are not limited to chemical oxidations using chemical oxidants, for example potassium dichromate and hydrogen peroxide, and/or using ozonation. One measure

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of oxidizability is an ozone reaction rate. Difficult to oxidize or non-oxidizable compounds have an ozone reaction rate less than or equal to the ozone reaction rate of pentachlorophenol and include but are not limited to pentachlorophenol (PCP), perchloroethylene (PCE), methylisobutylketone (MIBK) and carbon tetrachloride (CCl<sub>4</sub>), chloroethylenes including specifically tetrachloroethylene, and trichloroethylene, benzene, aliphatic alcohols, aldehydes, carbonic acids, specifically oxalic acid. There appears to be no limit to the concentration of the carbon-containing compound from about detectable limits to a super-saturated solution or mixture that may be altered in accordance with the present invention. The rate of alteration of the carbon containing compound(s) is determined by the rate of electrical energy expended.

Since Sharma '275 clearly teaches breakdown of chloro-phenols (e.g. PCP) in liquid form, there is no motivation to add Applicants' claimed extra (central) electrode. Thus, for reductive breakdown of non-oxidizable species such as chlorophenols, there is no motivation to add the liquid phase discharge provided by a central electrode based on the knowledge known by one having ordinary skill in the art that the liquid phase discharge primarily degrades through oxidation.

In view of I, II and III as described above, Applicants submit that there is no motivation to add an extra electrode to Sharma '275, such as Applicants' central ground electrode because the Sharma '275 two (2) electrode system already provides a liquid discharge, generates reactive liquid species, and efficiently breaks down phenols. Therefore, claim 1 and its respective dependent claims are patentable over the cited art.

Claim 16 is a method claim that has been amended to recite using the reactor recited in claim 1. Accordingly, amended claim 16 and its respective dependent claims are believed to be patentable over the cited art.

Claim 10 recites a reactor comprising:

at least a first electrode disposed in a liquid volume;

at least a second electrode disposed in a gaseous volume, said gaseous volume having an interface with said liquid volume; and

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at least one power supply connected to said first and second electrodes for generating a high voltage electrical discharges between said first and second electrodes, *wherein a zeolite comprising catalyst is included in at least one of said liquid volume and said gaseous volume.*

Claim 10 was rejected based on Sharma '275 in view of U.S. Pat. No. 6,130,182 to Naeem. According to the Examiner:

Regarding claim 10, Sharma et al. teach a reactor in Fig. 1. The reactor has a first electrode 114 disposed in the liquid volume. The reactor has a second electrode disposed in a gaseous volume. The gaseous volume has an interface with the liquid volume. There is a power supply for connecting the first and second electrodes such that a high voltage discharge is generated between the electrodes. (See Fig. 1; Column 6 lines 1-12)

The difference not yet discussed is the use of a zeolite catalyst (Claim 10).

Regarding the zeolite catalyst of claim 10, Naeem teach a reactor for corona destruction of volatile organic compounds. (See Abstract) The catalyst can comprise a substrate having a first layer of dielectric material, a first electrically conducting layer and a second layer of dielectric layer. (Column 4 lines 39-49) The dielectric layer of the catalyst can be a zeolite material. (Column 3 lines 35-37)

The motivation for utilizing a zeolite material as a catalyst is that it allows for removing a volatile organic compounds. (See Abstract)

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have modified Sharma et al. '275 by utilizing a zeolite

catalyst as taught by Naeem because it allows for removing volatile organic compounds.

Applicants respectfully disagree with the rejection of claim 10 based on Naeem. Naeem exclusively discloses treatment of air pollutants using zeolite catalysts in barrier discharge reactors. There are fundamental differences between catalyst activity in air for air pollution treatment and in water for water pollution treatment just as there are fundamental differences between the gaseous and liquid states. Specifically, liquid water is a highly polar liquid with a high electrical permittivity ( $\epsilon_r = 80$ ) and with a nonzero electrical conductivity  $\sigma$ . Water exposed to an electric field  $E$  for a time  $t$ , behaves as a dielectric if  $t \ll \epsilon/\sigma$ , while for  $t \gg \epsilon/\sigma$  it behaves as an ion semiconductor. The time constant  $\tau \equiv \epsilon/\sigma = 72$  ns for  $\sigma = 100$   $\mu\text{S/cm}$ . This means that in experiments the water solution behaves as an ion semiconductor.

An electric field ( $E$ ) of the order of 1 MV/cm is needed for initiation of the corona-like discharges in water solutions. Electrical discharges in water differ substantially from those in gases due to the nonzero electrical conductivity and the much higher particle density of the medium resulting in a low mobility of ions transferring the discharge current. The generated plasma in the liquid phase has no analogy to gas phase discharges. Thus, there is no reason to expect that catalytic activity of a catalyst such as the claimed zeolites in the liquid phase electrical discharge would have any relation to the effectiveness of zeolites in the gas phase electrical discharge or even in the liquid phase without electrical discharge. There is an abundance of literature on heterogeneous catalysts in the liquid phase for organic chemistry in general (reviewed in G. V. Smith and F. Notheisz, *Heterogeneous Catalysis in Organic Chemistry*. San Diego: Academic Press, 1999) and the chemistry is well recognized to be dramatically different from that in the gas phase.

Moreover, zeolites catalysts have been used for gas phase reactors (such as Naeem's) for several decades, but not for liquid phase reactors until Applicants' discovery. This evidences the

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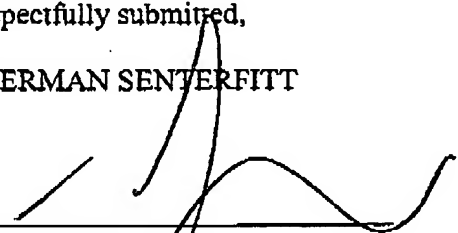
non-obviousness of Applicants' claimed reactor recited in claim 10, particularly in light of the superior degradation of contaminants provide by such a system. The results of such an inventive system is reported in Applicants' application in Example 2 entitled "Zeolites for Enhanced Degradation of Contaminants in Hybrid Corona Reactors". Figures 5-7 shows the significant reactor efficiency enhancement effect by the addition of three different zeolite catalysts to the liquid phase of reactors according to the invention. The results disclosed demonstrate significantly enhanced reactor efficiency as compared to the same reactor without zeolites, such as for the destruction of phenols. In view of points noted above, Applicants submit that amended claim 10 and its respective dependent claims are patentable over the cited art.

Applicants have made every effort to present claims which distinguish over the cited art, and it is believed that all claims are in condition for allowance. However, Applicants invite the Examiner to call the undersigned if it is believed that a telephonic interview (direct line (561) 671-3662) would expedite the prosecution of the application to an allowance. Although no fee is believed to be due, the Commissioner for Patents is hereby authorized to charge any deficiency in fees due or credit an excess in fees with the filing of the papers submitted herein during prosecution of this application to Deposit Account No. 50-0951.

Respectfully submitted,

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